Toxic Contamination in Sediments

Lake Saint-Pierre: Last Stop before the Estuary

Photo: Magella Pelletier, Environment Canada

A sediment core

Background

Particles eroded from the bed and banks of the St. Lawrence River and from the watercourses feeding into it remain suspended in the water for a fairly long time before settling on the bottom to form sediment. These successive layers of accumulated sediment constitute a veritable historical record of the natural and anthropogenic events that have shaped the St. Lawrence drainage basin.

Photo: Michel Asselin, Environment Canada

Aerial view of Lake Saint-Pierre Islands

Particles can act as traps for passing metals that may be toxic to benthic organisms. In addition, the industrial, agricultural and urban effluent discharges that mix with the particles contain organic material that could potentially be contaminated by pesticides, hydrocarbons or polychlorinated biphenyls.

Lake Saint-Pierre is a favourable environment for sediment accumulation. It is also, and has been for decades, subject to a great diversity of different sources of contamination. Thus, the sediments in Lake Saint-Pierre tell the story of the freshwater St. Lawrence.

Sheltered among its wetlands and sediment layers are a whole host of aquatic and benthic organisms. Lake Saint-Pierre is tremendously rich in biodiversity and its environment is especially dynamic, one that is subject to major water-level fluctuations. If we are to preserve this special place, though, we must first understand it.

Overview of the Situation

Designated as a Ramsar site in 1998 and a World Biosphere Reserve in 2000, Lake Saint-Pierre abounds with a unique plant and animal biodiversity. Upstream, several islands and shallow channels form a natural barrier to the flow of the river toward the St. Lawrence Estuary. Wrongly referred to as the delta of Sorel and Berthier, this island grouping was created over millennia by the erosive action of water on the postglacial clays of the Champlain Sea.

Favourable to Sediment Accumulation

Downstream of these islands, the sandy bed of Lake Saint-Pierre stretches over a distance of some thirty kilometres. The lake is an average three metres deep and seven to ten kilometres wide, so the current remains relatively strong over the entire lake. And yet there are still areas that favour the accumulation of sediment particles. The oldest sediments are found on the channel bottoms and in between and immediately downstream of the islands. We can reconstruct some of the history of the St. Lawrence River based on these sediments, particularly in the northern portion of the lake,

Figure 1. Location map of Lake Saint-Pierre

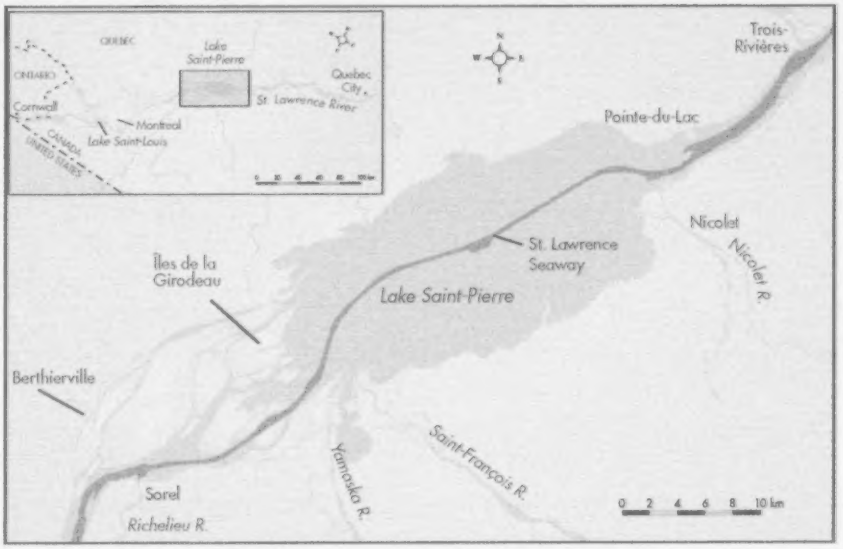


Figure 2. Distribution over time of mercury concentrations in sediment deposits downstream of the islands of Lake Saint-Pierre

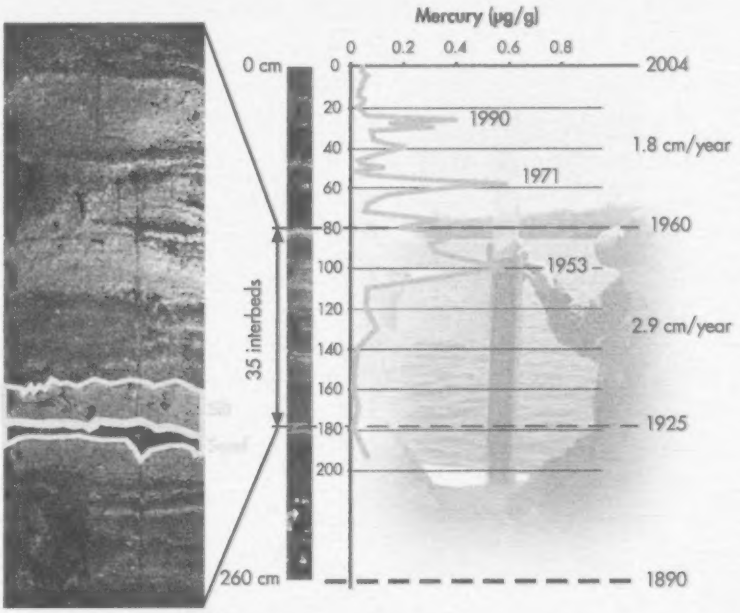


Photo: Michel Arsenault, Environment Canada

Sampling for sediments

Table 1. Average concentration of different toxic substances in sediment in the northern portion of Lake Saint-Pierre

	Average concentration (µg/g)								
	As	Cd	Cr	Cu	Ni	Pb	Zn	Hg	PCB
SAMPLING YEAR									
1976	–	8.4	106.3	74.5	31.3	46.7	208.8	0.51	–
1986	2.6	1.0	120.3	48.1	38.1	33.9	149.0	0.15	0.114*
2003	1.9	0.4	56.6	18.3	22.7	18.2	89.6	0.05	0.007**
IMPROVEMENT (%)									
From 1976 to 2003	–	96	47	75	28	61	57	90	–
From 1986 to 2003	26	64	53	62	41	46	40	67	94
PREINDUSTRIAL CONCENTRATIONS									
	7	0.2	60	19	29	13	86	0.08	–
SEDIMENT QUALITY CRITERIA									
TEL	6	0.6	37	36	–	35	120	0.20	0.030
PEL	17	4.0	90	200	–	90	320	0.50	0.300

* The average PCB concentration in 1986 is the sum of Aroclors 1242, 1254 and 1260.

** Congeners were used to calculate the approximate value of the average concentration of Aroclors 1242, 1254 and 1260.

TEL: Threshold Effect Level.

PEL: Probable Effect Level.

because the waters of the Ottawa River, the outfall waters of the city of Montreal and other smaller effluents don't mix with the river water proper.

Sedimentation that Varies by Event

Before the construction of overflow weirs between the islands of Lake Saint-Pierre to raise the water level in Montreal Harbour (1925–28), the accumulated sediment was composed solely of medium- to coarse-grained sand. Thereafter, over a period of 30-odd years, we find alternating layers of medium-grained sand and silt, which correspond to the spring and summer seasons in the river. Finally, around 1960, and with the annual opening of the shipping channel, sediment deposits show as a mixture of fine to medium-grained sand with silt. Although closely linked to the development of navigation on the river, sedimentation is equally affected by variations in the water level. Thus, during periods of low water levels (i.e. early 1930s and 1960s, 1999 and 2001), sediments are finer and silty, compared to periods of high levels (i.e. 1915, 1945, 1975), when sand predominates.

Basic Evolution of Contamination

Hand-in-hand with the industrial development and urban expansion of the province came the increasing contamination of the water and sediment in Lake Saint-Pierre by toxic substances like mercury and polychlorinated biphenyls (PCBs). Ancient sediments taken from the areas downstream of Îles de la Girodeau show a relatively

rapid increase, starting in the middle of the last century, in environmental concentrations of mercury. Also observed for levels of metals (copper, zinc, lead and nickel) and PCBs throughout the lake, this increase is the direct result of the use of these substances in a variety of industrial processes.

The concentrations of these different toxic substances gradually started declining in the mid-1970s until today, when values for metals approach background (natural) concentrations, the concentrations at which there is no effect on biota (in the case of organic substances like PCBs). As such, we must consider that the Montreal wastewater cleanup program, along with efforts to reduce toxic discharges by industry and the closure of some polluting industrial plants along the St. Lawrence River and its tributaries, have contributed greatly to improving the quality of the aquatic environment.

On a spatial scale, the geochemical data gathered between 1976 and 2003 show that the mercury concentrations measured in the northern portion of Lake Saint-Pierre have dropped by 90% in the last 30 years, going from a level deemed toxic to one that is clearly below the threshold effect level (TEL) on the aquatic environment. These concentrations have declined considerably since the startup of the Montreal wastewater treatment plant in November 1987. Only the upstream portion of the islands and the Chenal aux Castors receive higher concentrations, likely from the Ottawa River.

Figure 3. Spatial distribution of mercury in sediment in Lake Saint-Pierre in 1976, 1986 and 2000–2003

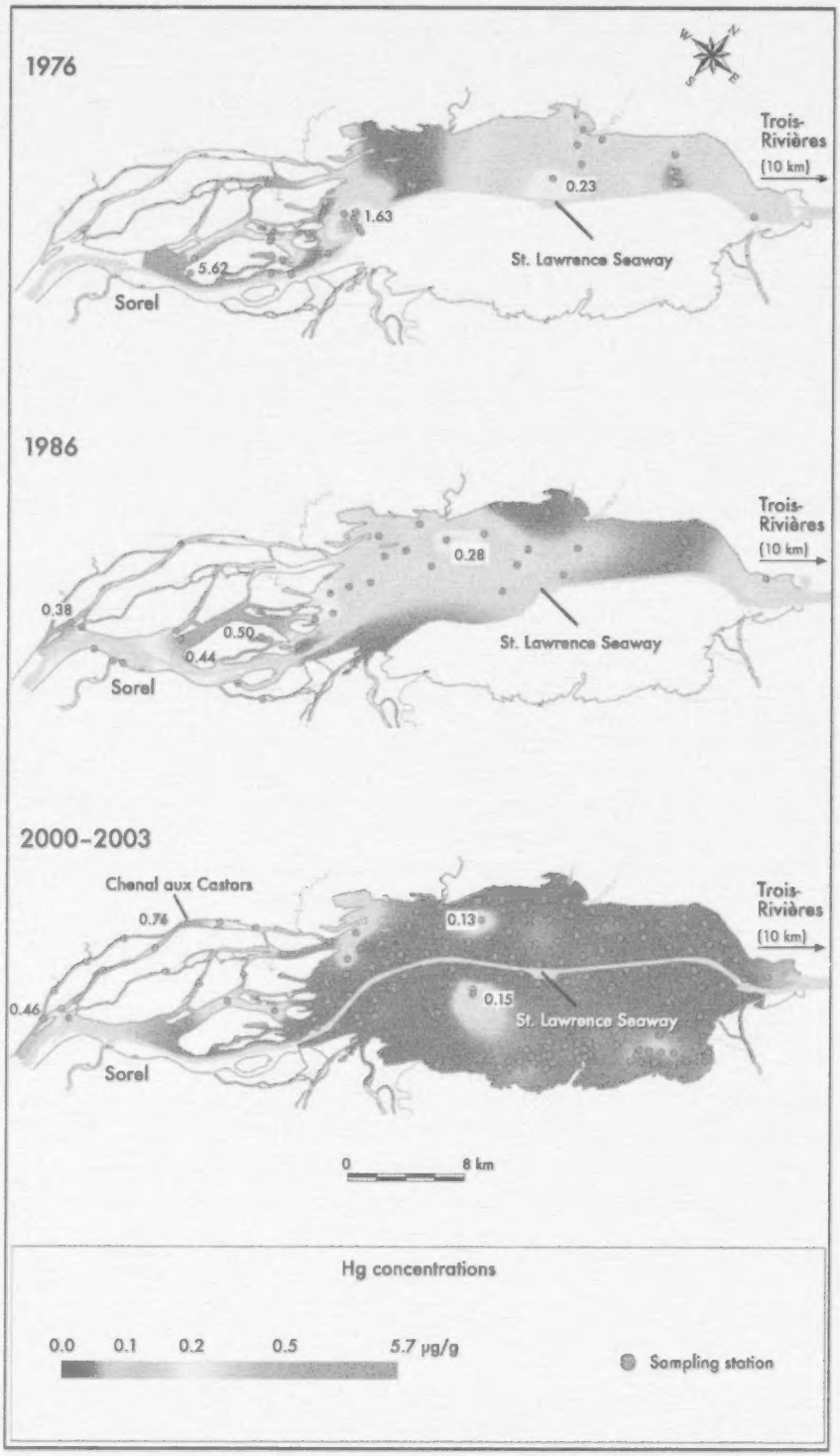
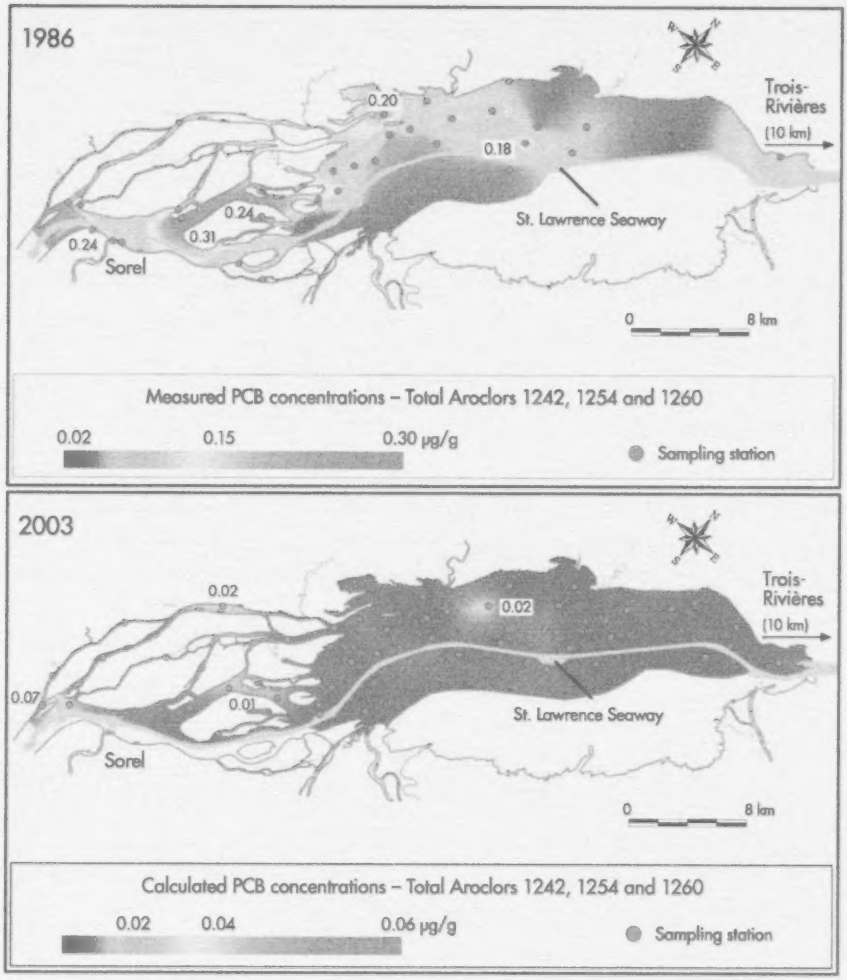


Figure 4. Spatial distribution of polychlorinated biphenyls in sediment in Lake Saint-Pierre between 1986 and 2000–2003



Although it is relatively difficult to compare PCB concentrations measured in 1986 with those from 2003 due to technical analytic differences, overall PCB levels have fallen by approximately 90–95% since 1986. It is highly probable that this decrease is related to the cleanup of Montreal's wastewater and to the general decline in PCBs in the St. Lawrence system over the past 20 years.

Metal concentrations in the northern portion of the lake have also declined since 1986; today, average values approximate those of preindustrial background levels. This drop in metal concentrations appears to be attributable to Montreal's wastewater cleanup initiatives, but they could also be just the general improvement in the environment.

Lastly, sediment characterization work conducted in 2003 found no large concentration of organochlorine pesticides or total phosphorus in sediment in the northern portion of the lake.

Photo: Caroline Savage, Environment Canada

Outlook

Present quality monitoring and contamination assessment activities are focused on the deep sediment layer (50+ years old), considered as a trap for toxic substances, and on surface sediment (10 last years), which is examined to characterize annual inputs of particles. Targeted monitoring is being conducted to take up-to-date snapshots of the situation of contaminants in the aquatic environment, determine the main anthropogenic events affecting benthic habitat, and assess the cumulative impacts of restoration measures on the lake environment.

In coming years we will be analysing for emerging substances like polybrominated diphenyl ether (PBDE), used as a flame retardant in household products, tributyltin (TBT), contained in boat paints, and dioxins and furans discharged by different industrial plants. This new data will provide us with a complete picture of the contaminants present in river water and ensure that the aquatic environment remains hospitable to benthic fauna. The three St. Lawrence lake environments will be compared to produce a thorough, spatially-based profile of contamination in the aquatic environment and to pinpoint the most contaminated sectors.

Over the years, new data-gathering activities will allow us to enhance our understanding of the sedimentary processes in the river environment, describe its overall geochemical status and determine short- and long-term trends in its chemical composition.

Photo: Magella Fellerat, Environment Canada

Photo: Caroline Savage, Environment Canada

Photo: Michel Arsenault, Environment Canada

KEY MEASURES

Criteria and Contamination Thresholds

Two types of tools are used to monitor sediment quality: sediment-quality criteria and the threshold of significant contamination (TSC).

The quality criteria define two levels of contamination: the threshold effect level (TEL) and the probable effect level (PEL). Below the TEL level, organisms are not considered as being affected by the different chemicals because concentrations are very low. Above the TEL level, the most sensitive organisms are possibly affected by toxic substances; above the PEL level, chemical concentrations are high enough to produce deleterious effects in organisms.

The threshold of significant contamination (TSC) applies only to metals and is defined by the anthropogenic enrichment factor (AEF). The AEF is the rate by which a contaminant exceeds its preindustrial concentration and to which a factor of 2.5 is applied to take account of natural variations. When the preindustrial level is not known, the AEF can be calculated using the TEL. We estimate that levels of contamination above the TSC can not be the result of variations in sediment texture or geology alone, but that a relatively substantial anthropogenic input is the cause.

Photo: Caroline Savoie, Environment Canada

To Know More

CUSSON, B. and A. LATREILLE. 2003. *Étude environnementale portant sur la qualité des sédiments de la portion sud du lac Saint-Pierre utilisée par le Centre d'essais et d'expérimentation en munitions* (CEEM) *de Nicolet*. Environment Canada – Quebec Region, Environmental Protection Branch. 179 pp.

HARDY, B., L. CHAMPOUX, H. SLOTERDIJK, and J. BUREAU. 1991. *Caractérisation des sédiments de fond du lac Saint-Pierre, fleuve Saint-Laurent*. Environment Canada, Conservation and Protection – Quebec Region, St. Lawrence Centre. 74 pp.

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State of the St. Lawrence Monitoring Program

Six government partners — Environment Canada, Fisheries and Oceans Canada, the Canadian Space Agency, Parks Canada Agency, the Ministère du Développement durable, de l'Environnement et des Parcs du Québec, the Ministère des Ressources naturelles et de la Faune du Québec — and Stratégies Saint-Laurent, a nongovernmental organization that works actively with riverside communities, are pooling their expertise and efforts to provide Canadians with information on the state of the St. Lawrence and long-term trends affecting it.

To this end, environmental indicators have been developed on the basis of data collected as part of each organization's ongoing environmental monitoring activities. These activities cover the main components of the environment, namely water, sediments, biological resources, uses and shorelines.

For more information on the State of the St. Lawrence Monitoring Program, please visit our Web site at **<www.planstlaurent.qc.ca>** or contact our offices at the following address:

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